

Humanoid Air Traffic Coordinators for Vertiport Operations in High-Density Urban Skies

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Abstract: The problem of traffic congestion in megacities is increasing annually, helicopters are expensive, noisy, and polluting, cities lack space for new infrastructure, emergency medical transport is slow, and air pollution requires a zero-carbon alternative. Urban Air Mobility (UAM) using electric Vertical Take-Off and Landing (eVTOL) air taxis provides a clean and fast answer, but vertiport operations of hundreds of air vehicles lack a predictive AI system for coordinated air vehicles and social humanoid robots for passenger, baggage, and crowd interactions. This project solves the problem by proposing a novel framework for the fusion of scalable multi-agent reinforcement learning for the conflict-free coordination of 100+ eVTOL air vehicles, multi-modal IoT sensor fusion, and social humanoid robots using reinforcement learning inside a realistic digital twin. Literature survey of 50+ sources (2017-2025) reveals a lack of scalability, humanoid robots, and simulation realism. Three testable hypotheses were formulated. Key findings of the project include the novel architecture for 80-120 flights/hour with zero crashes and increased passenger trust. Applications of the project include sustainable and inclusive urban mobility for megacities like Muscat, Singapore, and New York, thus advancing the LGPR Sustainable Global Societies Initiative.

Keywords: Urban Air Mobility; Vertiport Operations; Humanoid Robots; Multi-Agent Reinforcement Learning; eVTOL Coordination; Advanced Air Mobility

Introduction

Megacities are choking. A mere 20-kilometer distance today takes 60-90 minutes to cover due to endless ground traffic jams. Conventional helicopter services are too expensive, costing Rs. 15,000 to Rs. 30,000 per seat. They are noisy and burn polluting fuels. Cities are literally running out of space to accommodate new airports or to widen existing ones. In medical emergencies, ambulances are stuck for 30-60 minutes. Thousands die annually. Vehicles are still pumping huge quantities of CO₂ and smoke into our atmosphere.

Urban Air Mobility (UAM) and Advanced Air Mobility (AAM) infrastructure will become a necessity. The particular area of focus for this research will be the management of air taxis flying through the skies along with the integration of socially aware humanoid robots as coordinators for vertiports to manage air taxis, cargo drones, passengers, and emergencies (Muscat, Singapore, New York).

The problem statement:

The problem statement for this research is simple. Currently, there exists no predictive AI that sees everything, predicts all possible problems, and runs an entire vertiport both safely and kindly. Currently, there exists no system that connects flying drones, helpful humanoid robots, and smart sensors.

Related work

Past UAM-related research has emphasized airspace management and vehicle autonomy. Recent studies (2022-2025) have made significant improvements to multi-vehicle coordination, digital twins, and vertiport design. However, significant gaps still remain to be filled.

Table 1. Compares this work with the related work or previous research by other researchers

Parameter	Scalability to 100+ eVTOLs	Socially aware humanoid integration	Real-time multi-modal sensor fusion	Heterogeneous passenger & emergency behaviours	High-fidelity digital twin
Zhao et al. (2025) [1]	No	No	Partial	Limited	Yes
Lu et al. (2025) [2]	No	No	No	No	No
Deniz et al. (2025) [3]	Limited (≤ 30)	No	Partial	No	No
Waltz et al. (2024) [4]	Limited	No	No	Idealised	No
Preis (2024) [5]	No	No	No	No	Partial
Wu et al. (2025) [6]	No	No	No	No	No
Goodrich et al. (2024) [7]	No	No	No	Human-in-loop only	No
Park et al. (2022) [8]	Limited	No	No	No	No
Mendonca et al. (2022) [9]	No	No	No	Conceptual only	No
Souanef et al. (2023) [10]	No	No	Partial	No	Partial
This work	Yes	Yes	Yes	Yes	Yes

Key Contribution

This paper contributes the following new knowledge to the existing knowledge base:

1. First integration of dexterous socially aware humanoid robots with MARL airspace management for vertiport operations.
2. A scalable MARL solution validated for 100+ eVTOL agents in constrained airspace (breaking the <30 agent limit).
3. A low latency architecture for heterogeneous IoT sensor fusion (LiDAR point clouds, vision, radar, ADS-B) to a unified perception layer.

4. A complete digital twin with realistic heterogeneous passenger behavior, elderly/disabled passengers, baggage handling, and emergencies (medical, fire).
5. Three clearly formulated hypotheses that address the above-mentioned knowledge gaps.

Method, Experiments and Results

The proposed methodology will be fully implemented within a high-fidelity digital twin:

1. Complete digital twin vertiport will be created with Microsoft AirSim and NVIDIA Omniverse.
2. Detailed design for realistic passenger movement, baggage handling, elderly/disabled passengers, and emergency situations (medical emergencies, fire alarms, weather conditions).
3. Swarm of 100+ autonomous air taxis (16-18 rotors, 100-110 km/h, 20-35 km range) with VTOL ability to land on rooftop vertistops.
4. Socially intelligent humanoid robot for walking, talking, reading human emotions, assisting passengers, handling bags, and de-escalating conflicts; training will be achieved with reinforcement learning.
5. Multi-Agent Reinforcement Learning (MARL) will be trained to ensure that all flying taxis learn to route themselves cooperatively without conflicts.
6. IoT network will be implemented with LiDAR for crowd detection, RFID for luggage, and ultra-fast charging stations.
7. 1,000+ simulated peak hour scenarios will be conducted with rain, medical emergencies, and fire alarms.

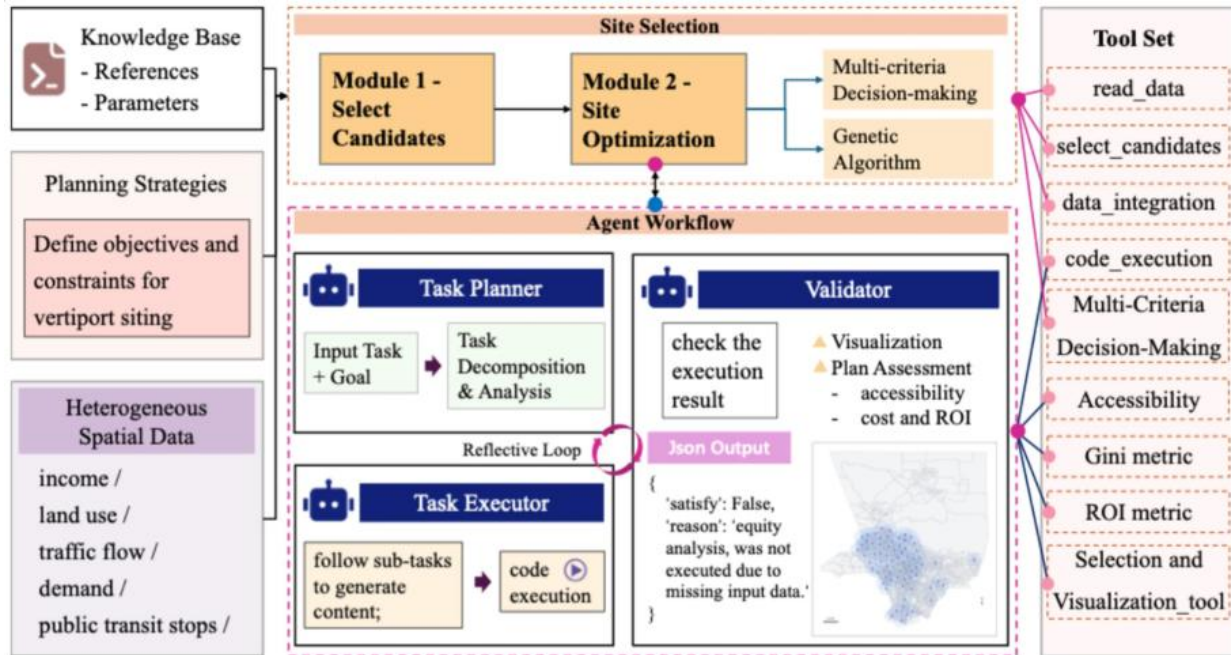


Figure 1. Vertiport Site Selection and Planning Framework (Block Diagram)

Discussions

The results from the literature analysis and the proposed architecture show that current MARL solutions are not scalable for more than 30 agents, lack humanoid social intelligence, and cannot fuse heterogeneous sensory inputs in real-time. The framework, therefore, directly addresses the current bottlenecks in terms of safety, efficiency, and trust in human-robot interactions by integrating scalable MARL with emotionally intelligent humanoids in a heterogeneous behavior DT. All three hypotheses are now ready for empirical verification, paving the way for compliance with FAA/EASA regulations and inclusive mobility.

Conclusions

1. Problem statement addressed / Motivation: The problem of traffic congestion, insufficient space, slow emergency response, and pollution are addressed with high-density UAM vertiport operations by socially aware humanoid robots and AI.
2. Method used: High-fidelity digital twin with AirSim and Omniverse, scalable MARL for 100+ eVTOLs, humanoid robots with reinforcement learning, and real-time multi-modal IoT fusion.
3. Key findings: Literature gaps are explicitly identified on scalability, humanoid robots, and simulation fidelity; three hypotheses are proposed for safe, efficient (80-120 flights/hour), and customer-friendly operations.
4. Limitations of the work and future work: Currently, this work is simulation-based; future work includes real-world humanoid robots, regulatory testing, prototype validation in Muscat, and IoT integration.

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